ACCURACY OF THE APPLE WATCH SE IN MEASURING DISTANCE AND MAXIMUM HEART RATE DURING A 6-MINUTE WALK TEST IN CARDIAC REHABILITATION PATIENTS

Tanachon Ungamrung, Phatra Meesuksabai

Department of Physical Medicine and Rehabilitation Medicine, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok, Thailand

Abstract

Background: A 6-Minute Walk Test (6MWT), a submaximal functional test, is widely used in cardiac rehabilitation. Wearable devices, such as a smartwatch, offer a substantial benefit by potentially replacing manual processes.

Objectives: This study aimed to assess the accuracy of a smartwatch in measuring distance and maximum heart rate during a 6MWT.

Methods: The study was conducted at the Cardiac Rehabilitation Clinic, Phramongkutklao Hospital, Bangkok, Thailand. Fifty-five Thai adults aged 20 to 75 years with cardiovascular diseases who attended an outpatient Cardiac Rehabilitation Program were enrolled into the study. Before the 6MWT, participants were fitted with a smartwatch and monitored via EKG telemetry. Upon completing the test, the distance and the maximum heart rate from the smartwatch were recorded. A standard measuring wheel and EKG telemetry were used as reference standards to assess the smart watch's accuracy.

Results: The mean distances recorded by the measuring wheel and the smart watch were 415.15 ± 72.26 meters and 475.29 ± 88.1 meters, respectively ($p < 0.001$). The intraclass correlation coefficient (ICC) for distance was 0.897 (95% CI: 0.823–0.94, $p < 0.001$). The maximum heart rates measured by EKG telemetry and the smart watch were 103.09 ± 13.19 bpm and 101.67 ± 13.93 bpm ($p = 0.172$), respectively, with an ICC of 0.915 (95% CI: 0.854–0.95, $p < 0.001$).

Conclusion: The smartwatch provides accurate maximum heart rate measurements and reliable distance measurements during 6MWTs in an indoor cardiac rehabilitation setting. However, calibration for the distance measured by the smart watch may be necessary.

Keywords: smart watch, 6-minute walk test, cardiac rehabilitation, maximum heart rate.

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Correspondence to:
Meesuksabai P, Department of Physical Medicine and Rehabilitation Medicine, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok, Thailand
E-mail: tongpkm@gmail.com

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Introduction

Cardiovascular diseases, including valvular heart disease and coronary artery disease, are among the leading causes of mortality worldwide. Regular preventive exercise is vital for mitigating the risk of developing these conditions.[1] Cardiac rehabilitation is a multidisciplinary intervention for patients with cardiovascular disease that provides tailored and safe exercise programs. These programs facilitate a patient's return to work, improve overall quality of life, reduce morbidity and mortality, and shorten hospital stays.[2]

The 6-Minute Walk Test (6MWT) is a submaximal exercise test commonly used to evaluate the functional capacity of patients with chronic conditions affecting the heart and lungs. It is widely adopted because it is easy to administer and its outcomes more accurately reflect daily activities than those of other tests.[3] Consequently, the 6MWT has been integrated into cardiac rehabilitation protocols across various stages of care.[4] However, administering and interpreting the 6MWT in routine clinical practice presents several challenges. The test requires substantial space and can be time-consuming, as current guidelines recommend conducting a second test to obtain more reliable results.[3,5-7] Furthermore, recent research suggests that smartphone-based measurements in clinical settings closely align with home-based 6MWT results.[8]

At the Cardiac Rehabilitation Clinic of Phramongkutklao Hospital, the 6MWT requires a single staff member and a 20-meter course and typically takes more than 6 minutes to complete. The sole staff member must perform several tasks throughout the test. These responsibilities include assessing baseline perceived exertion using the Borg scale, preparing the lap counter and timer, and continuously monitoring the patient for adverse symptoms, such as chest pain, severe dyspnea, or staggering, which may necessitate stopping the test. Finally, the staff member is responsible for documenting the total distance covered, specifically noting any distance beyond the last complete lap. This study aimed to identify and validate a tool that could automate simple tasks, allowing personnel to focus entirely on the patient's clinical status and safety during the test. Wearable devices, such as a smartwatch, offer a substantial benefit by potentially replacing the manual processes of counting laps and measuring partial distances, thereby increasing the efficiency and safety of the 6MWT.

Methods

Study design

This cross-sectional study was conducted at the cardiac rehabilitation medicine outpatient clinic at Phramongkutklao Hospital in Bangkok, Thailand, between May 2023 and October 2023. Although the minimum required sample size was calculated at 40 patients, 55 eligible patients were ultimately included to enhance statistical power and improve the generalizability of the findings. The study protocol received ethical approval from the Institutional Review Board of the Royal Thai Army Medical Department (I0437/66).

Participants

Inclusion criteria were Thai adults aged 20 to 75 years with a diagnosis of cardiovascular disease, including valvular heart disease and coronary artery disease, who could ambulate without a gait aid and were participating in outpatient cardiac rehabilitation. The study procedures were thoroughly explained to all patients, and written informed consent was obtained before enrollment. Patients with contraindications for the 6MWT, as defined by the American Thoracic Society (ATS), were excluded. These contraindications included amputation of both hands, resting blood pressure exceeding 180/100 mmHg, wrist tattoos, a history of carotid artery surgery, and cardiac arrhythmia. Patients who could not walk for the full six minutes were also excluded.

A 6-minute walk test

Participants were fitted with wireless electrocardiogram (EKG) telemetry and instructed to walk at their own pace for 6 minutes along a straight, 20-meter pathway, back and forth. If fatigued, patients were permitted to stop or reduce their walking speed without interrupting the timer. Following ATS guidelines, the examin-

er announced the remaining time at 1-minute intervals. The total distance traversed was recorded in meters. Equipment for the 6MWT included a countdown timer, a mechanical lap counter, two cones to mark turnaround points, worksheets, a sphygmomanometer, EKG telemetry, and a measuring wheel.

Before the 6MWT, participants were instructed to wear the Apple Watch SE (2nd generation, 2023) on their left wrist, positioned just above the ulnar styloid. They were then guided to update their personal information (age, height, weight, and sex) in the Health App profile to ensure accurate VO2 Max calculations and step-based distance estimates. Participants were explicitly instructed to launch the standard preinstalled "Workout" application and select the "Indoor Walk" program to track their distance and heart rate during the test. The smart watches used in this study were acquired independently by the research team, and neither Apple nor any external commercial entity provided financial or material support. Upon completion of the 6MWT, the differences in distance measurements between the Apple Watch SE and the measuring wheel were calculated, along with the differences in maximum heart rate between the Apple Watch SE and EKG telemetry.

Outcome measurements

The primary outcome was the validity of distance measurements obtained from the smartwatch compared with those from a measuring wheel. The secondary outcome was the validity of the smartwatch's maximum heart rate measurements compared with EKG telemetry.

Statistical analysis

Descriptive statistics were used to summarize baseline and clinical characteristics, using means and standard deviations (SD) for continuous variables and frequencies and percentages for categorical variables. A dependent t-test was used to evaluate differences in distance and maximum heart rate measurements. The intraclass correlation coefficient (ICC) was used to assess agreement between the two devices. Bland-Altman plots were used to visualize the distribution of differences between the measurements. Statistical significance was established at a $p < 0.05$.

Results

The study included 55 patients, with a majority being male (74.55%). The mean age of the patients was 60.05 years, with a mean body mass index (BMI) of 24.95 kg/m². A total of 69.09% of patients had a left ventricular ejection fraction (LVEF) exceeding 50%, and 96.36% had underlying medical conditions (**Table 1**). The distances recorded by the measuring wheel and the Apple Watch Series SE were 415.15 ± 72.26 m and 475.29 ± 88.1 m, respectively, a statistically significant difference (**Table 2**). The ICC for these distance measurements was 0.897 (95% CI: 0.823–0.94, $p < 0.001$) (**Table 3**).

Table 1. Demographic data and clinical characteristics of the participants (n=55)

Characteristics	
Age (years)[1]	60.05 (11.09)
Body mass index (kg/m²)[1]	24.95 (3.47)
Male[2]	41(74.55)
Left ventricular ejection fraction (>50%)[2]	38(69.09)
Diagnosis[2]	
Coronary artery disease (CAD)	37 (67.27)
Aortic dissection	7 (12.72)
Valvular heart disease	15 (27.27)
Other	2 (3.64)

Table 1. Demographic data and clinical characteristics of the participants (n=55)

Characteristics	
Underlying disease[2]	
Diabetes mellitus	21 (38.18)
Hypertension	42 (76.36)
Dyslipidemia	36 (65.45)
Chronic kidney disease	7 (12.73)
Other	12 (21.82)
Post operation (month)[2]	
<1	1 (1.82)
1-3	20 (36.36)
4-6	21 (38.18)
>6	13 (23.64)
Beta blocker[2]	37 (67.27)
FBS[1]	105.76 (18.19)
LDL[1]	90.12 (39.49)
Smoking[2]	0(0)

[1]Mean (SD), [2]Number (%), FBS: fasting blood sugar, LDL: low-density lipoprotein.

Table 2. Compare measuring wheels and a smart watch

	Measuring Wheels Mean ± SD	Smart Watch Mean ± SD	Differences (95%CI)	*p*-value
6MWT Distance (m)	415.15 ± 72.26	475.29 ± 88.1	60.15 (46.83, 73.47)	<0.001
HR max	103.09 ± 13.19	101.67 ± 13.93	-1.42 (-3.47, 0.64)	0.172

Paired t-test, Significant if $p < 0.05$

The maximum heart rates measured by EKG telemetry and the Apple Watch Series SE were 103.09 ± 13.19 bpm and 101.67 ± 13.93 bpm, respectively, and were not statistically significantly different (**Table 2**). The ICC for the maximum heart rate measurements was 0.915 (95% CI: 0.854–0.95, $p < 0.001$) (**Table 3**).

The Bland-Altman plot demonstrated a mean difference in distance of 60.15 m between the measuring wheel and the Apple Watch Series SE. The mean difference in maximum heart rate between the Apple Watch SE and EKG telemetry was -1.42 bpm (**Figure 1)**.

Discussion

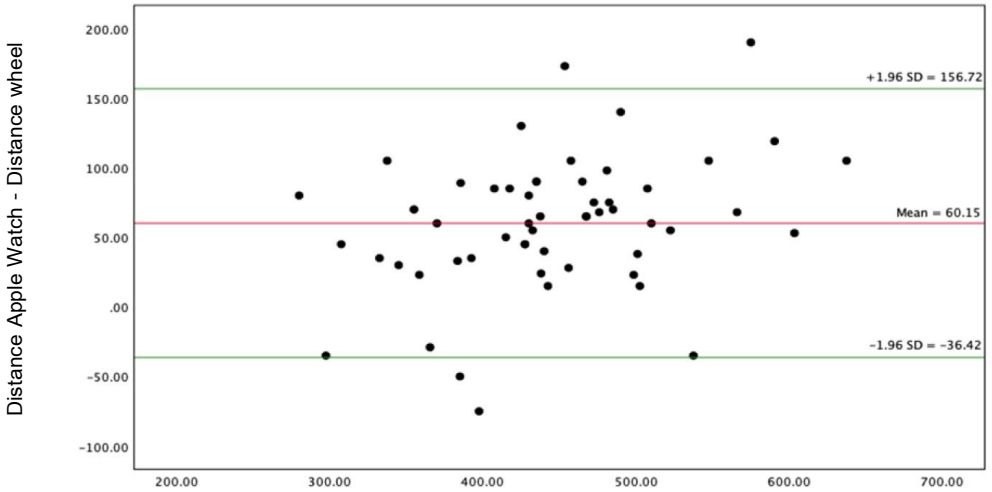
The main finding of this study is that the smartwatch (Apple Watch SE 2nd generation, 2023) provides an accurate measurement of maximum heart rate but overestimates distance covered during a 6-Minute Walk Test (6MWT) in cardiac rehabilitation patients. Although this discrepancy in the measured distance was present, the ICC indicated good reliability (95% CI: 0.897). However, this ICC value was lower than the 0.97 (95% CI: 0.97-0.98) reported by Stienen et al.[9] In a related study published in May 2021, the Apple Watch Series 4 demonstrated a validity of ±1.55 meters and a reliability ICC of 0.925[10].

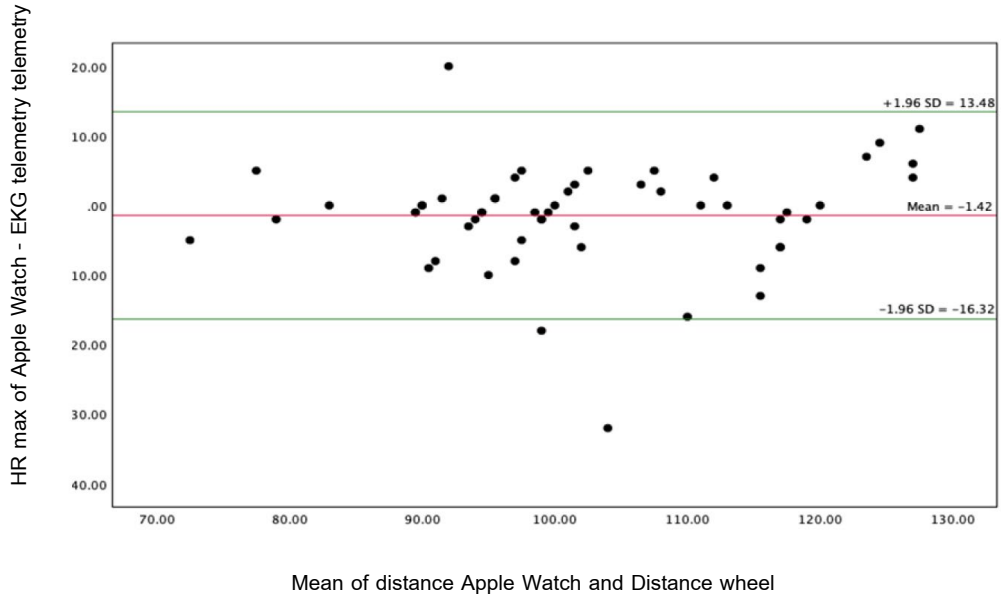
Table 3. Intraclass concordance correlation coefficient

	ICC	95%CI	*p*-value
6MWT Distance (m)	0.897	0.823 - 0.94	<0.001
HR max	0.915	0.854 - 0.95	<0.001

The intraclass concordance correlation coefficient
Significant if p < 0.05

- Distance (m)





- HR max: maximum heart rate, EKG telemetry: electrocardiogram telemetry Discussion

Figure 1: Bland-Altman plot

In relation to the study's objectives, these findings suggest that the smartwatch can be a reliable tool for monitoring patients during the 6MWT. The overestimation of distance may be attributed to the measurement methodology: the measuring wheel records distance in a straight line (20 meters) multiplied by the lap count, whereas patients walk a slightly curved path around the turnaround cones, resulting in a longer actual path than the smart watch captures. This systematic difference, combined with the device's high reliability, indicates that it could be effectively used in clinical practice. Critically, the successful automation of distance and heart rate measurement minimizes staff's manual recording and counting tasks, allowing the sole staff member to shift their focus entirely to the patient's clinical status and safety, thereby fulfilling the study's primary objective of enhancing patient monitoring efficiency. However, a calibration adjustment may be necessary to align with standard measurement techniques. Furthermore, the excellent accuracy of the maximum heart rate measurement is consistent with the findings of Khushhal et al.[11] This demonstrates that the photoplethysmography (PPG) sensor technology in the smart watch can accurately measure heart rate during physical activities such as walking. This reinforces its utility for safely monitoring cardiac response during submaximal exercise.

The primary limitation of this study was the limited walking space: patients walked a 20-meter course, which deviates from the 30-meter course recommended by ATS guidelines.[12] The shorter course required multiple turns, which may have impacted the accuracy of the distance measurements. Future studies should investigate whether increasing the distance between cones on a standard 30-meter course would lead to more accurate distance measurements. Additionally, further studies could investigate whether the device's accuracy varies with the total distance covered during the 6MWT, to understand its performance across different functional capacities.

Conclusion

The Apple Watch SE (2nd generation, 2023) provides accurate maximum heart rate measurements and reliable distance measurements during a 6MWT in an indoor cardiac rehabilitation clinic. The device's utility is crucially demonstrated by its ability to automate key parameter tracking, reducing staff workload and allowing clinical personnel to focus entirely on patient safety and clinical observation during the test. Although distance calibration may be necessary, the smart watch is a reliable alternative for monitoring these parameters. The demonstrated accuracy in heart rate monitoring reinforces its use as a tool to encourage safer exercise by enabling real-time tracking of cardiac exertion. Future research should validate the device's accuracy in both indoor and outdoor environments to further assess its broader applicability in cardiac rehabilitation. For patients without access to a smartwatch, conventionally supervised 6MWT protocols administered by clinical staff remain the recommended standard of care.

Disclosure

The authors declare there are no conflicts of interest related to this study.

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